REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
	Technical Papers	

4. TITLE AND SUBTITLE

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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8. PERFORMING ORGANIZATION REPORT

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory (AFMC)
AFRL/PRS
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Edwards AFB CA 93524-7048

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

20020828 165

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Leilani Richardson
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
Unclassified	Unclassified	Unclassified	A		(661) 275-5015

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. 239.18

41 items enclosed

NASPOOTX TP-1998-Ø173

MEMORANDUM FOR IN-HOUSE PUBLICATIONS

FROM: PROI (TI) (STINFO) 5 Nov 98

SUBJECT: Authorization for Release of Technical Information, Control Number: AFRL-PR-ED-TP-1998-0173
Frank Mead, ET AL., "Lightcraft Technology Demonstrator"

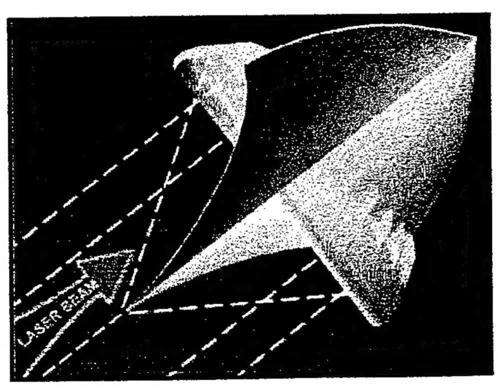
Web Site (Statement A)

The Lightcraft Technology Demonstrator (LTD) Program

NEW! Videos of recent Lightcraft flight experiments: 8 MB Quick Time, 8 MB AVI, or 4 MB MPEG.

The Air Force Research Laboratory's (AFRL) Propulsion Directorate at Edwards AFB, California, and the National Aeronautics and Space Administration's (NASA) Marshall Space Flight Center at Huntsville, Alabama, are jointly developing the LTD concept for launching 1 kg nanosatellites and eventually microsatellites weighing up to 100 kg into Low Earth Orbit. The program co-managers are Dr. Franklin Mead, Jr., a senior scientist at the Air Force laboratory, and Dr. Leik Myrabo, a professor at Rensselaer Polytechnic Institute (RPI) in Troy, New York. Dr. Myrabo is currently on academic leave from RPI and working full time at the Air Force laboratory with Dr. Mead.

The main purpose of this program is to develop a new low cost space transportation system using a laser propulsion concept in which the engine remains on the ground. Thus, the most expensive asset is never at risk. But although the LTD represents a novel form of propulsion, it is also a different concept of launch vehicle integration with payload. Each part of the craft ~~has been~~ conceived with multiple functions in mind, and the same component may serve various applications at different times during a mission into space. Thus, the payload is the propulsion system and the propulsion system ~~is the~~ payload. As an example, the primary mission of the LTD will be to receive and transmit electromagnetic signals using the 1 m optical surface that is used to focus laser light during propulsive maneuvers but can be used as a large diameter telescope once on station in space.



The LTD propulsion concept works by focusing laser light to a "ring" focal point at the inner surface of the shroud. ~~Thus the focussed laser light forms a circle.~~ This focussed laser light is so intense that it rips the air molecules apart and tears the electrons from the resulting atoms of oxygen and nitrogen, thus forming a high temperature plasma. This plasma is so hot, five to six times hotter than a chemical rocket engine, that it literally "explodes" out the back end of the Lightcraft, creating a short pulse of very high thrust. This explosion and expansion out the back of the vehicle is called a detonation. And it occurs at a rate of 28 times a second. In between laser detonations, fresh air rushes into the annulus or cavity where the laser is focussed. Thus, the Lightcraft "refreshes" itself with cold air before each pulse. There is no propellant on board the Lightcraft vehicles that are currently being tested. They use only the atmospheric air available to them as they are launched to higher and higher altitudes. Rocket engineers would say that this Lightcraft vehicle has an infinite specific impulse.

The first phase of the LTD program began during the summer of 1996 and is scheduled for completion in December 1998. The first experiments with a 20 cm Lightcraft weighing 2 kg were conducted in July 1996 at the High Energy Laser System Test Facility (HELSTF), White Sands Missile Range (WSMR), New Mexico. In fact, although the program management resides at Edwards AFB, all testing has been done at the Pulsed Laser Vulnerability Test System (PLVTS) at the HELSTF.

The second phase of the LTD program is scheduled to begin in January 1999. This portion of the development effort will use a 100 kW class CO_2 laser, assembled and operated in Test Cell #4 at the HELSTF, to launch Lightcraft vehicles vertically to the edge of space (~ 30 km).

Read the most recent technical paper , and get a list of references.

What's happening: the latest experiments, progress, and TV shows.

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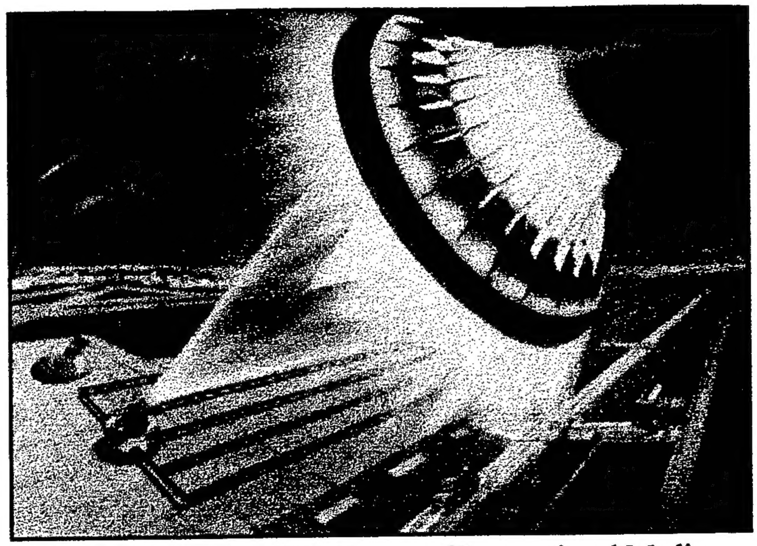
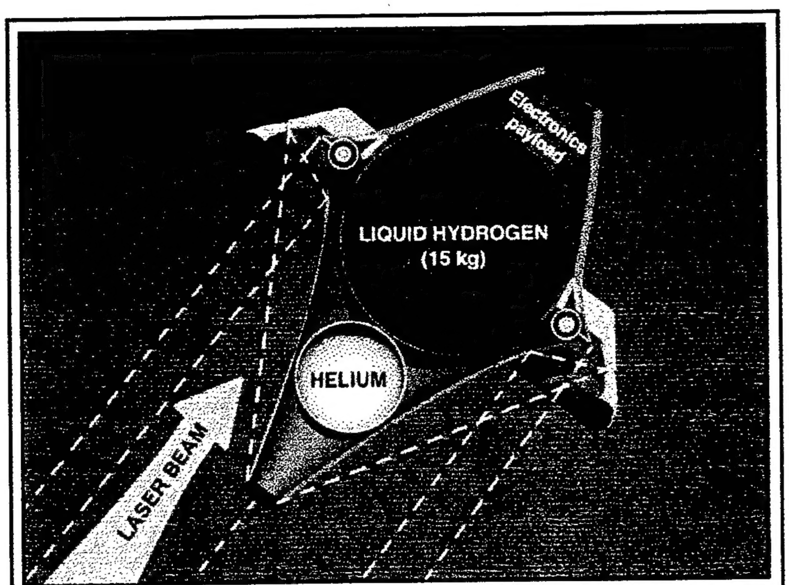
The LTD Concept

The "Lightcraft Technology Demonstrator (LTD)", is a laser propelled trans-atmospheric vehicle (TAV) concept developed by Prof. Leik Myrabo of Rensselaer Polytechnic Institute for Lawrence Livermore National Laboratory and the SDIO Laser Propulsion Program in the late 1980's. The dominant motivation behind this study was to provide an example of how laser propulsion could reduce, by an order-of-magnitude or more, the production and launch costs of sensor satellites. This novel launch system, utilizing both airbreathing and rocket propulsion modes (dual mode), was envisioned to employ a 100 MW-class ground-based laser to transmit power directly to an advanced combined-cycle engine that would propel a 120 kg (dry mass), 1.4 m diameter LTD, with a mass fraction of 0.5, to orbit. During launch, it was scheduled to transition from airbreathing to rocket mode at Mach 5 and 30 km.



Illustration, by Ronald K. Levan of Instructional Media Services, of the launch of a full scale Lightcraft from a high power laser facility at some time in the not-to-distant future.

The LTD concept was, and is today, a microsatellite in which the laser propulsion engine and satellite hardware are intimately shared. The forebody aeroshell acts as an external compression surface (i.e. the airbreathing engine inlet). The afterbody has a dual function as a primary receptive optic (parabolic mirror) for the laser beam and as an external expansion surface (plug nozzle) during the rocket mode. The primary thrust structure is the annular shroud. The shroud serves as both inlet and impulsive thrust surface during the airbreathing mode. In the rocket mode, the annular inlet is closed, and the afterbody and shroud combine to form the rocket thrust chamber. The three primary structures (forebody, shroud, and afterbody) are interconnected by a perimeter support frame to which all internal subsystems are attached. Once in orbit, the single-stage-to-orbit (SSTO) LTD vehicle becomes an autonomous satellite capable of delivering precise, high quality information typical of today's much larger orbital platforms.



Conceptual cutaway of a full scale operational Lightcraft.

Launch of an ultralight Lightcraft involves several steps. First, the Lightcraft is engaged by the laser and lifted off the launch stand. It then accelerates at a fixed angle (say 60° upward) toward Mach 5. With higher speeds and lower air pressure (due to increased altitude), the amount of thrust will decline. At 30 km altitude, the airbreathing pulsejet engine is shut off. The vehicle continues to coast upward along a ballistic trajectory through the region of the Paschen minimum pressure. At the desired altitude, the craft pitches over into its final horizontal position and begins to receive laser power from a low-altitude relay satellite. The Lightcraft, now in rocket mode, begins again to increase speed to that needed for a circular orbit.

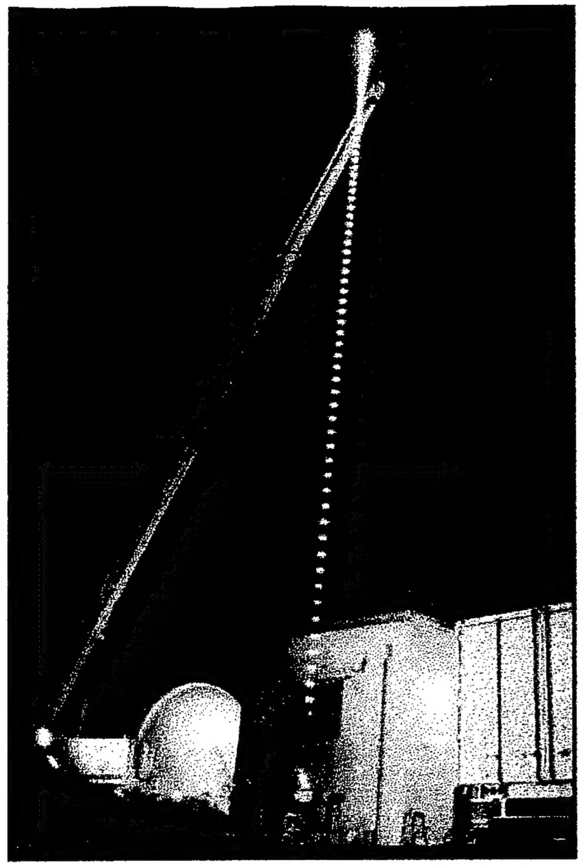
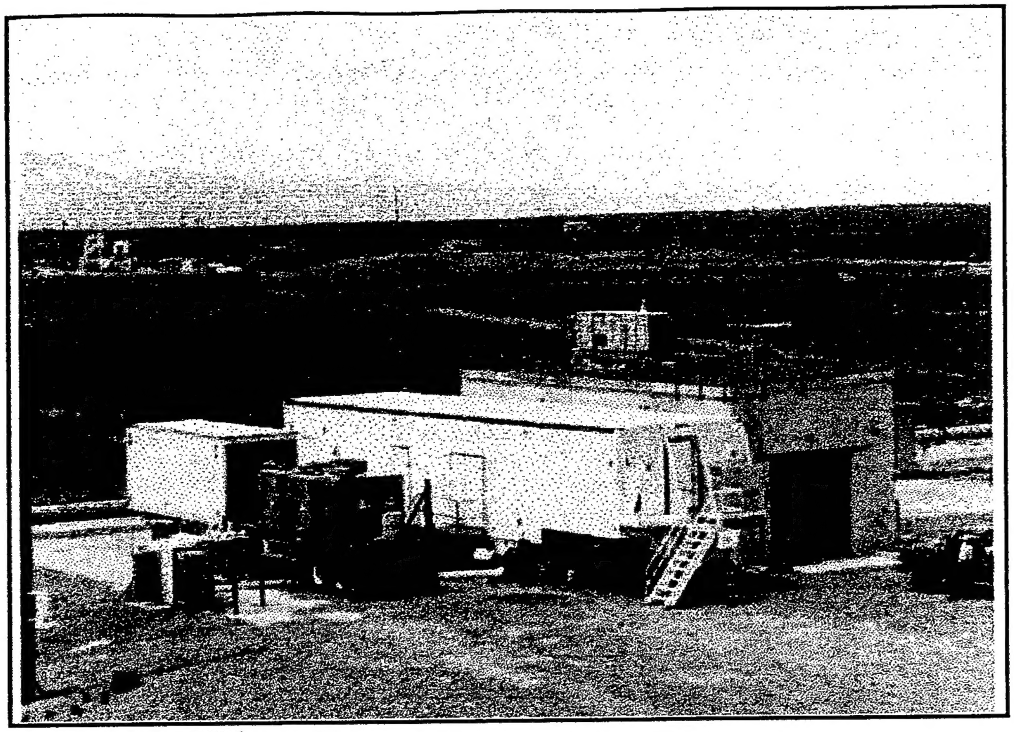


Figure 1 - December 1997 night launch of Lightcraft at the High Energy Laser System Test Facility, White Sands Missile Range, NM

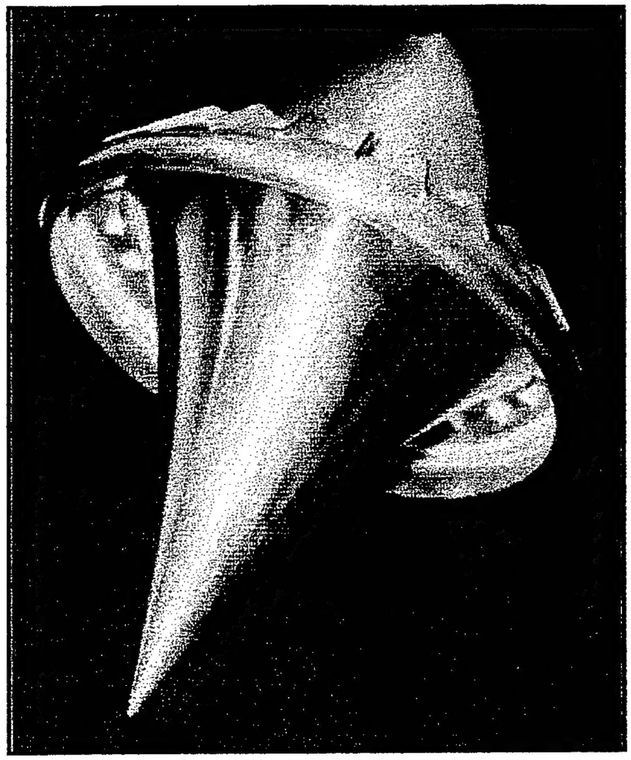
If a relay satellite is not available, then a different launch trajectory must be employed. Again, the Lightcraft is engaged by the laser and lifted off the launch stand. It then accelerates at an initial angle of about 30°, which is maintained ~~at~~ for 50 s into the flight. From then on, the Lightcraft trajectory is allowed to arc over under the influence of gravity in such a way that it attains orbital velocity of 8,000 m/s at a distance of 500 km and a final angle of 19.5°. However, this trajectory places the Lightcraft in a highly ellipitical orbit which would cause the vehicle to re-enter the atmosphere half an orbit around the earth. Therefore, a small solid rocket will be required to circularize the orbit. Using a small "kick" rocket in this way should enable circular satellite altitudes of up to 2,000 km.



All testing of the Lightcraft has taken place at HELSTF with the Pulsed Laser Vulnerability Test System (PLVTS). The PLVTS is a 10 kW, CO_2, electric discharge laser of moderate to high energy per pulse. It consists of several subsystems mounted in portable vans/trailers. This high energy CO_2 pulsed laser device is an AVCO-built HPPL-300 laser. The device uses an electron beam to excite the CO_2 gas and create the lasing action. It is a pulsed wave, closed cycle CO_2 laser with a pulse repetition rate of 1 to 30 pps (selectable), and a pulse width of 18 μs. The PLVTS beam can be extracted from the system by one of two methods. The primary method is through a static Beam Pointing Telescope (BPT). The BPT is a 50-cm cassegrainian telescope which allows manual pointing and focusing of the HEL beam to spell out downrange targets. The second method, and the method used for the Lightcraft tests to date, is through simple turning flats which redirect the 10-cm square beam to an external experimental package for testing. Although designed to operate as a stand-alone system, the PLVTS is homesteaded at Test Cell 3 at HELSTF. When operated at HELSTF, the PLVTS can be integrated with the existing HELSTF control, diagnostics, and data acquisition systems based on internal computers.

The Lightcraft as a Transmission/Rece~~i~~ption Telescope

The primary mission of the full-scale Lightcraft in space will most likely be for the transmission of electromagnetic information, i.e., as a communication satellite for send/receive transmissions. In this case, the primary mirror or "optic", commonly called the afterbody because it is to the rear in laser propelled operations, would serve a dual purpose on each mission. However, since the mirror has been designed primarily for propulsion applications, its performance in other respects may require special optical corrections to be applied. Studies in the past using ray trace analysis have indicated that this parabolic surface will have superior light gathering ability, but the angular field of view will be limited to about 0.5 degrees. Coma appears to be the dominant aberration over the entire field of view. A small abount of astigmatism may be present for the larger angles of incidence, while other aberrations are essentially negligible. Analyses of special mechanical subsystems developed to deploy an advanced segmented photo-optic sensor (a "ring retina"), into the focal region of the primary mirror transformed the propulsive optics into a powerful one meter diameter telescope. Thus, for a low earth orbit of 180 km, the resolution in the optical wavelengths ranges from 8 cm to 15 cm. For the 10.6 μ wavelength light from a CO_2 laser, the resolution is 233 cm at the same altitude.



20 cm diameter focus Lightcraft, weighing 2 kg, was used early in the program for coupling coefficient measurements.

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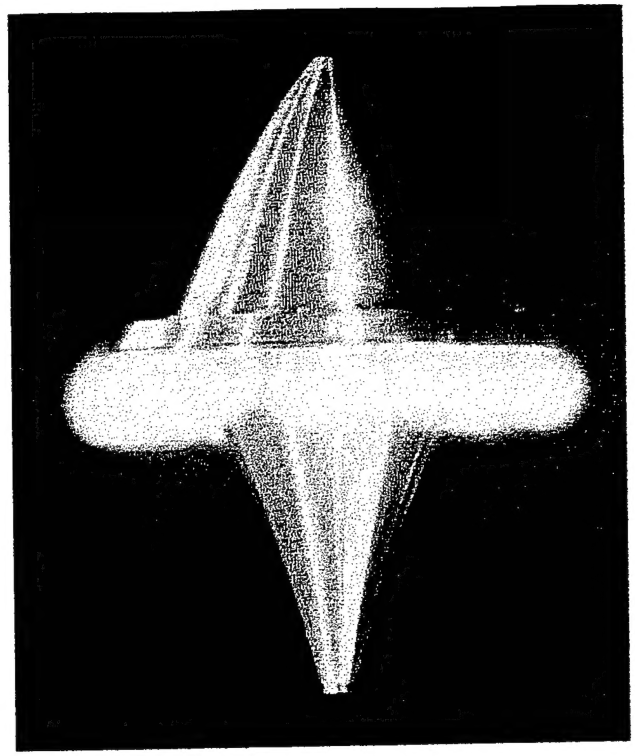
Lightcraft Plasma



A Plasma is a very high temperature quasi- not necessary neutral gas of charged and neutral particles which exhibits collective behavior.. ~~And~~ C collective behavior merely means that the particle motions in the gas depend not only on local conditions but are effected by conditions in remote regions of the plasma as well. In other words, a plasma is a gas in which the temperature is so hot that the molecules have broken down to their elemental atoms, and those atoms have lost some or all of their electrons. Thus, the plasma consists of ionized atoms and electrons all randomly moving around at very high velocities. Plasmas, because of their charged particle electrical nature, can be influenced by electric and magnetic fields. Some early tests at the Naval Research Laboratory showed that the thrust of a Lightcraft could be doubled by applying a magnetic in such a way as to cause a magnetic nozzle to exist. Plasma temperature is measured in terms of "electron volts (eV)". One electron volt equals 11,600 degrees Kelvin. The Lightcraft plasma is initially three to four eV. And what makes it really unique is that it is at a very high pressure. Its pressure initially is ~~at~~ thousands of atmospheres~~, pressure~~. These temperatures and pressures are what cause the plasma to "explode" out the back of the Lightcraft producing a very large "pulse" of thrust. The luminous Lightcraft plasma typically extends about a centimeter past the lip of the shroud. But, if one looks very closely, one can see a faint luminosity extending far out the back of the Lightcraft and flowing in a curved trajectory parallel to the optical surface which is acting like a plug nozzle or "Aerospike". Thus, the Lightcraft exhaust contour will be able to compensate for altitude and the decreasing pressure during its launches into space.

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October 26, 1998

TO: Dr. Franklin Mead
Dr. Leik Myrabo
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FROM: Sandy Kirkindall
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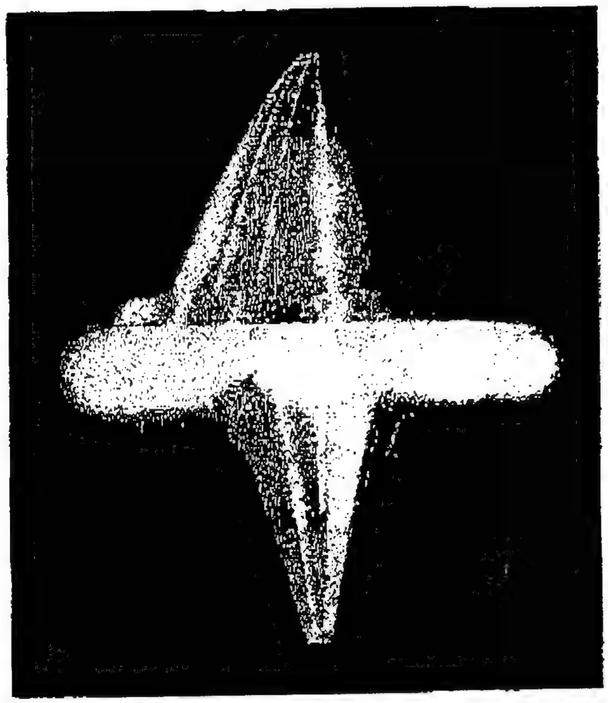
NASA, Marshall Space Flight Center
Phone: 256-544-7233
Fax: 256-544-7400

Frank/Leik:

I am enclosing some proposed editorial corrections to the faxed web page layouts you sent.

Sandy

Lightcraft Plasma



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Should this be 3 or 4?

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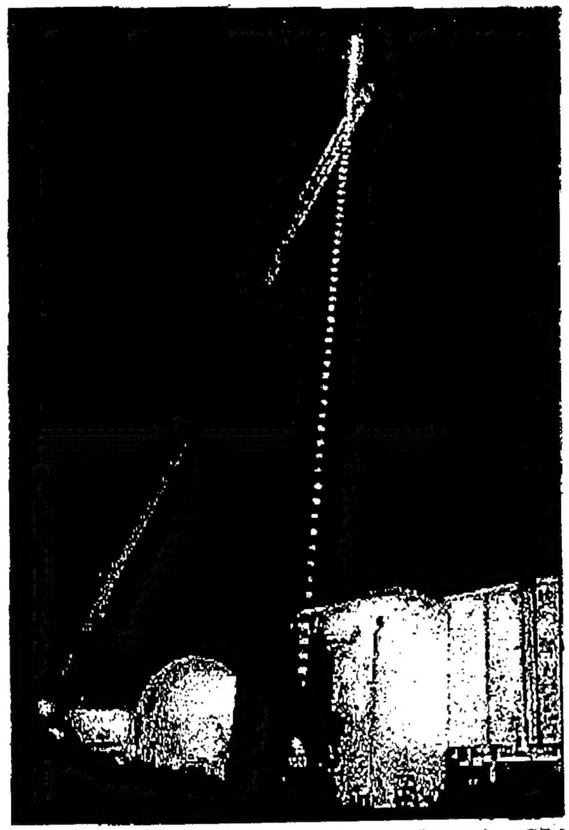

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for 50 seconds

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Academic training as a mechanical and aerospace engineer is in the thermal sciences (thermodynamics, fluid dynamics, and heat transfer), electric propulsion, and plasma dynamics (including fusion). Has over 25 years experience with advanced propulsion and energy concepts, is a nationally recognized expert in the subject, and is skilled in multi-discipline aspects of "advanced" physics & engineering technology. Professional experience has involved experimental and program/contract management of R&D level and advanced development efforts, including flight experiments and demonstrations. Currently directs the search for innovative and revolutionary propulsion concepts in pursuit of paradigm altering as well as evolutionary concepts that will enhance the Air Force's mission capability. Typical subjects worked on include fusion propulsion, various plasma concepts, unified field theory, zero point vacuum energy, magnetic field propulsion, and faster-than-light travel. Experience includes having worked with various chemical, electric, solar, and nuclear propulsion thrusters and system concepts.

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spelling

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After receiving his Ph.D. degree, he spent a total of seven years at Physical Sciences, Inc., W. J. Schafer Associates, and the BDM Corporation respectively, as a scientist/consultant in directed energy, space prime power, and advanced propulsion research. He joined the Rensselaer Polytechnic Institute facudy in 1983. His research interests and activities have included advanced propulsion and power technology, hypersonic gas dynamics, energy conversion, space technology, and directed energy. Currently, he is conducting theoretical and experimental studies on innovative aeronautical, and space flight propulsion concepts for the year 2005 and beyond. The specific area currently under investigation is the application of beamed energy and field propulsion engines for future air-breathing/rocket shuttlecraft. Promising beamed electromagnetic power compatible engine cycles include detonation wave engines, scramjets, electric air-turborockets, rotary pulsejets, and a unique variety of airbreathing electrostatic thruster.

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